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Innovative Urban Wet-Weather Flow Management Systems

By

James P. Heaney
Department of Civil, Environmental, and Architectural Engineering
University of Colorado
Boulder, CO 80309

Robert Pitt
Department of Civil and Environmental Engineering
The University of Alabama at Birmingham
Birmingham, AL 35294

and

Richard Field
Water Supply and Water Resources Division
National Risk Management Research Laboratory
Edison, NJ 08837

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Project Officer

Chi-Yuan Fan
Water Supply and Water Resources Division
National Risk Management Research Laboratory
Edison, NJ 08837

NATIONAL RISK MANAGEMENT RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OH 45268

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Foreword

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E. Timothy Oppelt, Director
National Risk Management Research Laboratory

Abstract

This research project describes innovative methods to develop improved wet weather flow (WWF) management systems for urban developments of the 21st century. This document addresses the competing objectives of providing drainage services at the same time as decreasing stormwater pollutant discharges. Water quality aspects of WWF discharges and associated receiving water problems have only been studied for a relatively short period (a few decades), compared to conventional drainage designs (a few centuries), and few large-scale drainage systems adequately address both of these suitable objectives.

General principles of urban water management are presented that might permit the development of more sustainable systems by integrating the traditionally separate functions of providing water supply, collecting, treating, and disposing of wastewater, and handling urban WWF. Integration can be achieved by designing neighborhood scale, integrated infrastructure systems wherein treated wastewater and stormwater are reused for nonpotable purposes such as lawn watering and toilet flushing. The automobile is seen to have caused major changes in urban land use in the 20th century. For the average urban family, the area devoted to streets and parking in their neighborhood exceeds the area devoted to living. Similarly, more area is devoted to parking than to office and commercial space in urban areas. The net result of the large scale changes to accommodate the automobile in cities is about a two to three fold increase in impervious area per family and business activity.

The physical, chemical, and biological water quality characteristics of urban runoff are evaluated and summarized. Then, the impacts of urban WWF on receiving waters are evaluated. These impacts on surface and groundwater are complex and difficult to evaluate. Physical changes in smaller urban streams can be detected in terms of degraded channels from higher peak flows. Also, sediment transport characteristics change with urbanization. Toxic effects on aquatic organisms have been detected.

Traditionally, wet-weather collection systems were designed to move stormwater from the urban area as quickly as possible. This design approach often simply transferred the problem from upstream to downstream areas. More recently, restrictions on the allowable maximum rate of runoff have forced developing areas to include onsite storage in detention ponds to control these peak rates of runoff. On-site detention also allows smaller pipe sizes downstream. In the early part of the 20th century, communities relied on combined sewers. Later, separate storm and sanitary sewers became accepted practice. However, as the need to treat more contaminated storm water becomes more apparent, it is necessary to take a fresh look at combined sewers. However, because of the strong trend to lower density urban development to accommodate the automobile, the quantity of urban runoff per family is two to three times what it was with higher density developments. Most of the traffic flow in cities occurs on a relatively small percentage of streets, about 10-20%. Also, most parking areas are underutilized. Thus, it may be possible to focus WWF treatment on these

more intensively used areas including commercial and industrial areas. This finding suggests that hybrid collection systems may be attractive alternatives for 21st century collection systems. Another innovative option is to oversize sewer systems and utilize storage in the sewers as part of a real-time control system.

Extensive discussions regarding the effectiveness of a wide variety of WWF controls are presented in two chapters. These descriptions include design guidelines. Source controls as well as downstream controls are included. Source area controls, especially biofiltration practices that can be easily implemented with simple grading, may be appropriate in newly developing areas. In addition, critical source areas (such as vehicle service facilities) may require more extensive onsite treatment strategies. An innovative approach is to reuse stormwater within the same service areas for irrigation, toilet flushing, and other nonpotable purposes. More aggressive stormwater reuse systems would capture roof runoff in cisterns, treat this water, and use it for potable purposes. Monthly water budgets for cities throughout the United States indicates that sufficient quantities of precipitation are generated, except in the arid southwestern United States, to make such systems technically feasible. The cost of providing for water infrastructure is summarized. The traditional problem of finding the optimal size of service area for water supply is addressed by finding the minimum sum of the costs of source acquisition, treatment, and distribution. For wastewater and stormwater, the minimum total cost is the sum of collection, treatment, and disposal. These costs per residence have grown substantially as development densities have decreased. Also, if wastewater and stormwater reuse are included, then the optimal size of infrastructure system may be at the neighborhood scale since piping costs remain the largest single cost in urban water infrastructure.

Lastly, institutional arrangements need to change in order to successfully implement changes in how urban water infrastructure is managed. Privatization, moving from large centralizes systems to neighborhood based systems, and other projected changes required innovative changes in the governing institutions.

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Abbreviations and Acronyms

A	Area
AASHTO	Association of State Highway and Transportation Officials
ac-ft	Acre-foot
ADT	Average daily traffic
AMSA	Association of Metropolitan Sewerage Agencies
APWA	American Public Works Association
ASCE	American Society of Civil Engineers
AWRA	American Water Resources Association
AWWA	American Water Works Association
AWWARF	American Water Works Association Research Foundation
BASINS	Better Assessment Science Integration Point and Nonpoint Sources
BCW	Boulder Creek Watershed
BMP	Best management practice
BOD	Biochemical oxygen demand
C	Runoff coefficient (in Rational method)
C of V	Coefficient of variation (standard deviation/mean)
CCA	Copper, chromium, arsenic
COD	Chemical oxygen demand
CSO	Combined sewer overflow
CY	Calendar year
DBO	Design-build-operate
DCIA	Directly connected impervious area (See IA)
DSS	Decision support systems
DU	Dwelling unit
DUD	Dwelling unit density
DWF	Dry weather flow
EPA	U.S. Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FHA	Federal Housing Administration
FHWA	Federal Highway Administration
fps	Feet per second
ET	Evapotranspiration
gpcd	Gallons per capita per day
gpd/idm	Gallons per day per inch diameter per mile
GIS	Geographic information system
ha	Hectare
HCR	High rain intensity, Clean, and Rough street
HCS	High rain intensity, Clean, and Smooth street
HDR	High rain intensity, Dirty, and Rough street
HDS	High rain intensity, Dirty, and Smooth street
HOV	High occupancy vehicle
HUD	U.S. Department of Housing and Urban Development
I	Imperviousness

IA	Impervious area (See DCIA)
IBDU	Isobutylidene diurea
I/I	Infiltration and/or inflow
ITE	Institute of Transportation Engineers
ISS	Integrated storm-sanitary system
J	Julian day number (e.g., J=365 for December 31)
kl	Kiloliter
l	Liter
L	Length of street per dwelling unit
lb/ft^2	Pound per square foot
LCE	Life-cycle engineering
LCR	Light rain intensity, Clean, and Rough street
LCS	Light rain intensity, Clean and Smooth street
LDR	Light rain intensity, Dirty, and Rough street
LPS	Low pressure sewers
m	Meter
MCTT	Multi-chambered treatment train
mgd	Million gallons per day
ml	Milliliter
mm	Millimeter
MMI	Man-machine interface
MTBE	Methyl-tert-butyl ether
MTBSC	Mean time between service calls
MVS	Modern vacuum system
N/m^2	Neuton per square meter
NAREUS	North American End Use Study
NCRS	National Resource Conservation Service (formerly, SCS, Soil Conservation Service)
NMC	Nine minimum controls
NPDES	National Pollution Discharge Elimination System
NPS	Non-point source
NSF	National Science Foundation
NURP	Nationwide Urban Runoff Program
NWS	National Weather Service
O&M	Operation and maintenance
OIA	Other impervious area
OWRR	Office of Water Resources Research
P	Precipitation (inches)
PAH	Polycyclic aromatic hydrocarbons
PD	Population density
PET	Potential evapotranspiration
POC	Purgable organic carbon
PSCO	Public Service Company of Colorado
R	Runoff volume
RCRA	Resource Conservation and Recovery Act
ROW	Right of way

RPE	Runoff producing event
RTC	Real time control
SCADA	Supervisory control and data acquisition
SCS	Soil Conservation Service (now the NRCS, National Resource Conservation Service)
SDC	System development charges
SDGS	Small diameter gravity sewer
SOV	Single occupancy vehicle
STD	Standard deviation
STEP	Septic tank effluent pumping
SS	Suspended solids
SSES	Sewer System Evaluation Survey
SSO	Sanitary sewer overflow
STORM	Storage, Treatment, Overflow and Runoff Model
THM	Trialomethane
TND	Traditional neighborhood development
TOC	Total organic carbon
TSS	Total suspended solids
µm	Micrometer
UF	Urea formaldehyde
ULI	Urban Land Institute
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
UV	Ultraviolet
UWRRC	Urban Water Resources Research Council (of ASCE)
VMT	Vehicle miles traveled
VOC	Volatile organic compound
WARMF	Watershed Analysis Risk Management Framework
WEF	Water Environment Federation
WET	Whole effluent toxicity
WSIUA	Water sustainability in urban areas
WWF	Wet weather flow

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